International Journal of
Environmental Sciences & Natural Resources
ISSN: 2572-1119

Juniper Publishers
key to the Researchers

Research Article
Volume 9 Issue 1 - March 2018
DOI: 10.19080/IJESNR.2018.08.555755

Int J Environ Sci Nat Res

Evaluation of the Impacts of Eucalyptus Plantation on Macro-Invertebrate Assemblage in the Aquatic Environment, South Western Ethiopia

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Submission: January 08, 2018; **Published:** March 09, 2018

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Abstract

The anthropogenic disturbances of the streams in south-western Ethiopia have increased throughout last century due to increased land use and Eucalyptus tree plantation. Despite this there is lack of knowledge on the impact of eucalyptus plantation on macroinvertebrate assemblages. In this study, we have evaluated the impacts of eucalyptus plantation on the ecological integrity of selected streams in the Gilgel Gibie River watershed, Ethiopia. Water samples and macroinvertebrate samples were taken from Eucalyptus dominated sites and none Eucalyptus riparian vegetation sites. Physicochemical parameters were measured onsite and in the laboratory. Similarly, the leaf litters of Eucalyptus grandis, Croton macrostachyus, Ficus sure and Salix subserrata were collected from the riparian zones of the streams. Non-metric Multidimensional Scaling analysis was used to test the level of similarity between none Eucalyptus and Eucalyptus macroinvertebrate diversity and water quality. Besides, types of vegetation, physicochemical and macroinvertebrate relationship were analyzed using Canonical Correspondence (CCA) and Test statics Analysis. The total of 3,133 macroinvertebrate individuals belonged to 36 families and 9 orders were identified. The Most abundant orders were recorded in none Eucalyptus vegetation was Ephemeroptera 44% followed by Tricoptera 16%, While in Eucalyptus vegetation stream the most abundant macroinvertebrates recorded Ephemeroptera 18% followed by Odonata 17%.

The water sample contains leaf litters of Eucalyptus grandis, Croton macrostachyus, Ficus sure and Salix subserrata were affecting the physicochemical parameters. For all sampled water the pH of Salix subserrata and Eucalyptus grandis leaf litters were less than seven while the pH of Croton macrostachyus and Ficus sure were above seven. For all water samples contain these leaf litters the electrical conductivity and TP were increased from time to time, but the EC of Croton macrostachyus more abrupt than the other leaf litter decomposition. These results highlight the need to protect the stream ecosystem from Eucalyptus plantation. There are different types of freshwater changes and hazardous substances increases, water quality and biological diversity in aquatic ecosystem decreases.

Keywords: Macro Invertebrate; Non-Eucalyptus; Eucalyptus; Leas Flitter; Water Quality

Introduction

In Ethiopia, ecological diversity and varied climatic conditions have been explained to a large extent as result of variable topography composition [1,2]. Water quality change and variable topography is increasingly becoming most of the critical domestic and global environmental policy concerns [3]. Ethiopia is threatened by environmental change and exposed to frequent drought, flooding, and rising of average temperatures. Therefore, as environmental pollutants in the glob such as sedimentation, fertilizers, sewage, runoff, erosion, dissolved oxygen, PH, temperature, decayed organic materials, pesticides, toxic and hazardous substances, oils, grease and other chemicals, detergents, heavy metals and litter of vegetations [4]. These are the major causes of destruction of water quality of rivers and streams [5,6].

Water quality has Eucalyptus tereticornis. Eucalyptus globulus and Eucalyptus grandis are the major species planted in the highlands of Ethiopia. Eucalyptus growing in Ethiopia is mostly confined to the highlands, where there are suitable moisture and temperature regimes [7]. Plantations of Eucalyptus grandis are known to negatively affect aquatic systems [8]. The replacement of the native vegetation by Eucalypt monocultures leads to changes in the stream hydrology, organic matter dynamics and litter quality; all factors have been concerned in the scarcity of macroinvertebrate communities in streams [9]. The presence of phenolic compounds in the media or adsorbed to alder leaves surface, lowering their nutritional value, may have been responsible for reducing or suppressing (according to the leachate concentration) consumption [10].

In the previous study there was no studied comparison between the distribution of shredders, collector/gatherer, collector/filterer, scrapers and predators with regarding to riparian and exotic plant leaf litter decomposition [11]. The impacts of Eucalyptus plants are aggravated to different country like Iberian Peninsula, Central Portugal [12]. Except in Ethiopia. This situation is not yet studied in Ethiopia, where Eucalyptus tree is widely used. Thus, this study to evaluate the impacts of Eucalyptus plant on macroinvertebrate composition and compare the effects of different leaf litters decomposition on physicochemical characteristics of water become a major concern across Ethiopia, long term monitoring of surface water quality and it is critical in determining if aquatic systems are being degraded [13].

Macroinvertebrates are considered to be as an indicator species; a species that can help to identify the state of the habitat condition it currently occupies. Macroinvertebrate studies are often used to evaluate overall water quality since these organisms can incorporate the impacts of short term variations over long time periods [14]. Biodiversity Macroinvertebrates were affected by different factors such as light, certain stressors, nutrient, temperature, habitat modification and degradation. Among all these habitat degradation and modification were the most common [15]. Habitat modification along riparian zone can affect species diversity, increased sediment and nutrient loads, increased erosion and siltation and other environmental variables [16,17]. Furthermore an introduction of exotic plant species like Eucalyptus resulted in the homogenization of freshwater faunas and macroinvertebrate at regional and local scales [18,19]. In Ethiopia, the most widespread species include *Eucalyptus camaldulensis, Eucalyptus citriodora, Eucalyptus globules, Eucalyptus grandis, Eucalyptus saligna,* and *Eucalyptus tereticornis* [20]. Eucalyptus globulus and Eucalyptus grandis are the major species planted in the highlands of Ethiopia. Eucalyptus growing in Ethiopia is mostly confined to the highlands, where there are suitable moisture and temperature regimes [21].

Methods and Materials

Description of Study Area

The study was conducted in Jimma zone on selected tributaries of Gilgel Gibe River, south-western Ethiopia (located latitude 70 25’-70 55’ and longitude 360 30’ - 37 22’ East). The Climate of Jimma is tropical rain forest region, with a temperature of 16.4 and an average of 116.7mm annual precipitation while the altitude ranges from 1096 to 3259m above sea level [22].The selected streams for the study that are flowing under Eucalyptus plantations and other vegetation are located in this region. The longitude, latitude and elevation of each sampling site were recorded using a GPS (global positioning system) reading (Figure 1). Indicates the studies area (Kechema and Bore stream) and the location of sampling stations. We have an independent variable Macroinvertebrate assemblages and dependent variables turbidity, electrical conductivity, temperature, pH, dissolved oxygen, total suspended solid, total nitrogen, total Phosphorous, habitat condition, non-eucalyptus vegetation and eucalyptus vegetation. Site selection was based on the fulfilment of the inclusion and exclusion criteria. The inclusion criteria were all sites have similar status in habitat condition; land use and anthropogenic activities and exclusion criteria were different vegetation type [23]. Based on the above criteria, 12 sites located under Eucalyptus and eight sites under none Eucalyptus vegetation were selected (Table 1). The minimum distance between the sampling sites were 200m.

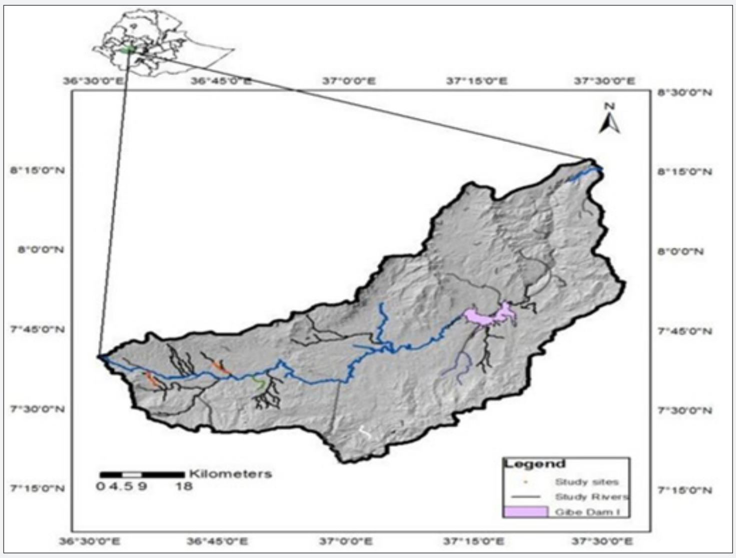

Figure 1: Location of the study area and selected tributary of Gilgel Gibe River, south-western Ethiopia, 2015. The red point of the map were indicates that the study sites of the river which flows under eucalyptus and non-eucalyptus vegetation with macro invertebrate assemblage.

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Table 1: Site characteristics of the study area in terms of vegetation, land use and habitat condition.

S/N	Streams Sample Station	Dominant vegetation	Land Use Mackenzie [42]	Habitat condition Barbour [5]
1	Kechema Upper Stream (K1-K3)	None Ecualyptus	Minimally Impact	Very good
2	Kechema downstream (K4-B9)	Ecualyptus	Minimally Impact	Very good
3	Bore Upper Stream (B1-B5)	None Ecualyptus	Minimally Impact	Good
4	Bore downstream (B6-B11)	Ecualyptus	Minimally Impact	Good

Habitat assessment (HAB) scores categorization criteria: optimal (excellent= 161-200), sub optimal (very good=121-160), marginal (good=60-120) and poor= 0-59 and land use score scale is 0 to 5 (0= None; 1= Low; 2=Moderate; 3=Large; 4=Serious; 5 =Extreme impacted).

Data Collection

Macroinvertebrate Sampling and Identification: At each site, all macroinvertebrates were collected by kick-net with in 10m distance of the stream flow within five minutes of sampling time. Then, sorted and put down into sample bottles containing 70% ethanol for preservation. Finally the bottles containing macroinvertebrate specimen were transported to laboratory of Jimma University for identification, counted and assigned to their taxonomic family level of macroinvertebrate under a light microscope and standard macroinvertebrate identification keys. All specimens were assigned to one of four major functional feeding groups, shredders, predators, collectors and filterers according to [24,25].

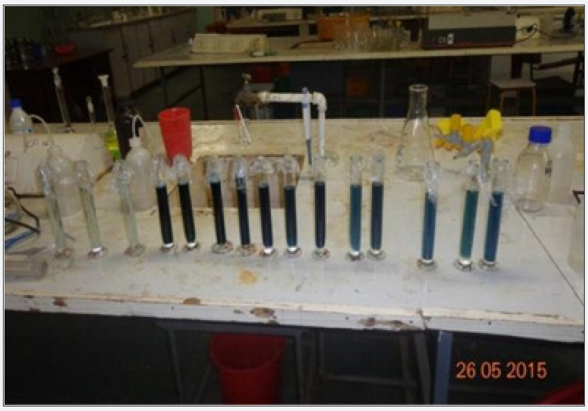

Figure 2: Analysis of total phosphorous and total nitrogen of field sample water which was taken from the river flow under *eucalyptus* and *non eucalyptus* vegetation in the laboratory using by kit or LCK 339.

Water Sampling: From each selected sampling site, water quality parameters were measured onsite and in the laboratory. Onsite measurement was done for dissolved oxygen (DO), temperature, pH and electrical conductivity (EC) using multi-parameter probe (HQd4 single input Multi-Parameter Digital Meter, Hatch) at each site and turbidity was measured using a wagtech (turbidity meter Wag-WT3020) after shaking the sample. Furthermore, the stream width and depth, and current velocity of stream were measured with tape water and flow meter respectively (Figure 2).

Leaf litter Preparation: Common leaf litters were collected from Gilgel Gibe River. These leaves were Eucalyptus grandis (Bahirzafe), croton macrostachyus (Bissana), Ficus sure forssk (Shola) and Salix subsessrata (Ye'akaya zafe) were collected and inserted to the jack. The leaf has to be air dried. The leaves in the jack were transported to the laboratory for comparison of the water quality parameter which was affected by four different leaves. Each leaves were measured 100g by beam balance in triplicate way and inserted to plastic jar and were lived for four weeks. 12 samples of triplicate of 100g of 4 different leaves were prepared.

Sample Water Arrangement: From the selected tributary of Gilgel Gibe River, 75 litter water samples were brought by plastic container and transported to the laboratory for water quality analysis. Five litre water samples were monitored in triplicate way to under taken follow up for the water quality change under this specific leaf litter. We have totally 15 water samples in plastic jar.

Monitoring of the Experimental Water in the Laboratory: The water quality parameters, turbidity, DO, EC, PH, Water temperature; TN and TP were measured before the water mix with that of selected leaves. The water parameters DO, EC, pH, turbidity and water temperature were measured for one month within three days gap while TN and TP were measured for one month within seven days gap.

Data Analysis

Descriptive Statistics

Descriptive statistics were employed to analyze the general information of physicochemical data used by stepwise forward selection method the most environmental indictors using past software package version 2, Statistica and IBM SPSS version 20. The diversity indices were organized for measurements of biodiversity in water ecosystem depends on the degree of pollution. Macroinvertebrates diversity was computed using

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different indices such as: Shannon index (H), Simpson index of diversity (1-D), Brillouin index, Fisher-alpha and Margalef's index. CCA is also a multivariate method to elucidate the relationships between biological assemblages of species and their environment. It is appropriate when the length of gradient is put down between 3SD and 4SD [26,27].

Non-Metric Multidimensional Scaling (NMDS)

NMDS is a means of visualizing the level of similarity of individual cases of a dataset. It refers to a set of related ordination techniques used in visualization in particular to display the information contained in a dominance matrix [28]. The following indices were tested on riparian plant data: species richness (S), the Shannon diversity index (H'), Simpson index (D) [29,30]. Descriptive statistics were used to analyse the general information of physicochemical data. A multivariate conical correspondence analysis (CCA) was used to method to elucidate the relationships between biological assemblages of species and their environment. It is appropriate when the length of gradient is put down between 3SD and 4SD [31]. A *Non-Metric Multidimensional scaling (NMDS)* was use to visualizing the level of similarity of individual cases of a dataset. It refers to a set of related ordination techniques used in visualization in particular to display the information contained in a dominance matrix [32].

Experimental Results

Physicochemical Characteristics of Water Quality

Across the 20 sites examined, the pH value of the streams under none Eucalyptus vegetation was ranged from 7.44 at site K1 to 7.81 at site K2 whereas the streams under Eucalyptus vegetation was ranged from 6.03 as site K5 to 7.05 at site k9. Electrical conductivity of the stream under none Eucalyptus vegetation was ranged from 113.5µS/cm at site K2 to 205µs/cm at site B5 while; in the stream under Eucalyptus vegetation was ranged from114.6 at site k6 to 206.3 at site B10. The rest detail summary of environmental variables at all sampling sites are shown in (Table 2).

Table 2: Summary statistics of Environmental variable in the sampling sites.

Vegetation type	Site	PH	Depth (m)	Width(m)	Turb (NTU)	Temp (0C)	DO (mg/L)	EC (µS/cm)	TN (mg/L)	TP (mg/L)	TSS (g/L)
None Ecualyptus	K1	7.44	0.35	4	28.4	20.8	7.27	114.1	2.56	0.04	28.2
None Ecualyptus	K2	7.81	0.24	4	20.1	19	7.76	113.5	2.54	0.02	20
None Ecualyptus	K3	7.66	0.24	4	20.9	20	7.98	115.5	2.51	0.03	16
None Ecualyptus	B1	7.72	0.01	1.9	21.6	18	6.41	186.9	0.99	0.07	26.4
None Ecualyptus	B2	7.76	0.05	1.6	17.3	17.5	6.58	186.5	0.92	0.07	21
None Ecualyptus	B3	7.59	0.05	1.5	16.22	17.5	6.83	186.4	1.4	0.09	23.2
None Ecualyptus	B4	7.75	0.06	1.3	13.47	20.7	6.37	196.4	0.93	0.01	11.2
None Ecualyptus	B5	7.66	0.05	1.7	13.24	21.2	6.15	205	4.43	0.12	13
Ecualyptus	K4	7.02	0.27	2.2	22.2	19.1	7.3	115.3	2.04	0.03	31
Ecualyptus	K5	6.03	0.37	1.9	21.8	19.6	7.17	116.5	1.82	0.04	16.4
Ecualyptus	K6	7.05	0.3	3	21.4	18.9	7.37	114.6	2.46	0.06	54
Ecualyptus	K7	7.04	0.27	2.3	20.3	18.9	7.17	116.4	2.02	0.01	54
Ecualyptus	K8	7.02	0.34	2.2	20.4	18.5	7.25	117.3	2.27	0.01	44
Ecualyptus	K9	7.05	17.3	2.45	22.6	19.3	7.26	116.5	2.25	0.01	38
Ecualyptus	B6	7.00	0.4	1.9	17.6	20.2	6.56	213.6	0.43	0.05	43.3
Ecualyptus	B7	6.04	0.05	2.1	12.69	18.9	6.92	191.2	0.58	0.04	32
Ecualyptus	B8	7.04	0.09	1.8	6.92	18.7	7.36	200.4	0.44	0.03	44
Ecualyptus	B9	7.01	0.05	2	10.24	18.7	5.57	205.2	0.69	0.04	38
Ecualyptus	B10	7.02	0.05	1.8	8.62	18.2	4.73	206.3	0.75	0.04	58
Ecualyptus	B11	7.01	0.03	1.9	30.4	19.8	4.95	189.1	0.88	0.01	109

Where Turb=Turbidity, Temp=Temperature, DO=Dissolved Oxygen, EC=Electricity Conductivity, TN=Nitrate Nitrogen (or) Total Nitrogen, TP=Total Phosphorous, TSS= Total Suspended Solid, M=Meter, mg/L= Milligram per Liter, g=gram, NTU= nephelometric turbidity units, µS/cm= Micro Siemens per Centimeter, 0C= degreecentigrade

Macroinvertebrates Description

From 20 sampling sites a total of 3133 individual macroinvertebrates belonging to 36 families and 9 orders were identified from all representative habitat types of the study sites.

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Macroinvertebrate Dominance

From the total number of macroinvertebrates order Ephemeroptera was dominant with the family of Beatidae and Caenidae in both streams were flow under Eucalyptus and none Eucalyptus vegetation. Order Diptera also dominant with the dominant family of Chironomidae in both streams were flow under Eucalyptus and none Eucalyptus vegetation (Table 3).

Table 3: Percentage of dominant order and taxa in selected tributary stream of Gilgel Gibe River, South-western Ethiopia, 2015 along Eucalyptus and none Eucalyptus vegetation.

Types of Vegetation	Order	% of Order	Family Level	% of Dominant taxa
None Ecualyptus	Ephemeroptera	43.59	Beatidae	34
None Ecualyptus	Ephemeroptera	43.59	Caenidae	33.7
None Ecualyptus	Ephemeroptera	43.59	Heptagenidae	32
None Ecualyptus	Tricoptera	15.6	Haydropsychidae	96
None Ecualyptus	Diptera	10.7	Chronnoidae	52
None Ecualyptus	Diptera	10.7	Simulidae	15
Ecualyptus	Ephemeroptera	18.15	Caenidae	53.4
Ecualyptus	Ephemeroptera	18.15	Beatidae	4.8
Ecualyptus	Ephemeroptera	18.15	Heptagenidae	4.8
Ecualyptus	Odonata	17.1	Coenagrionidae	61.26
Ecualyptus	Odonata	17.1	Corduliidae	14.41
Ecualyptus	Odonata	17.1	Aeshenidae	9.9
Ecualyptus	Diptera	8.65	Chironomidae	94.06
Ecualyptus	Diptera	8.65	Simulidae	4.79

Distribution of Macroinvertebrate along Vegetation Type

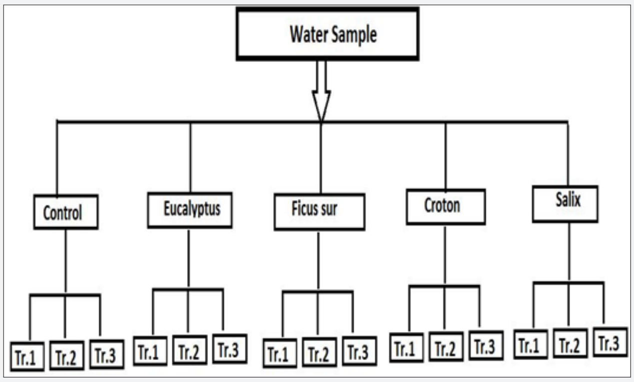

Figure 3: water sample, mixing of 100g leaf litter with prepared water and experimental diagrams explain the arrangement of the four different leaves tests in triplicate way for thirty days at laboratory scale, Sam= sample, Tr 1,2,3= Triplicate 1,2,3.

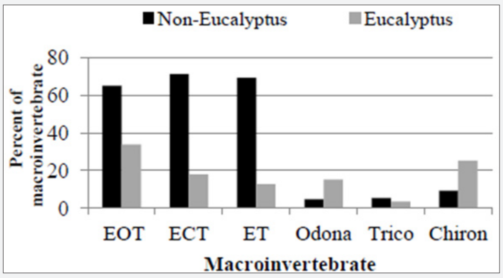

Figure 4: Percentage of EOT, ECT, ET, Odonata, Tricoptera and Chironomidae along vegetation type in Kechema and Bore streams of Gilgel Gibe River, southwestern Ethiopia 2015.

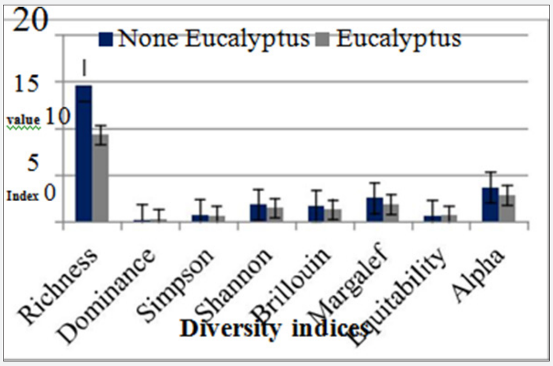

Figure 5 : The average value of diversity measures in the two study groups. The error bar indicates the standard deviations among the different diversity indices.

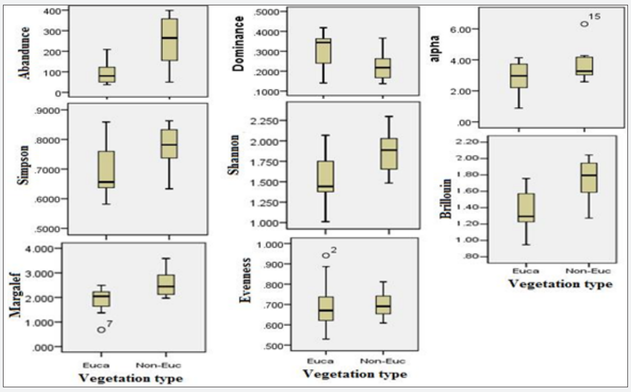

Figure 6: Box plots of indices along vegetation type scale.

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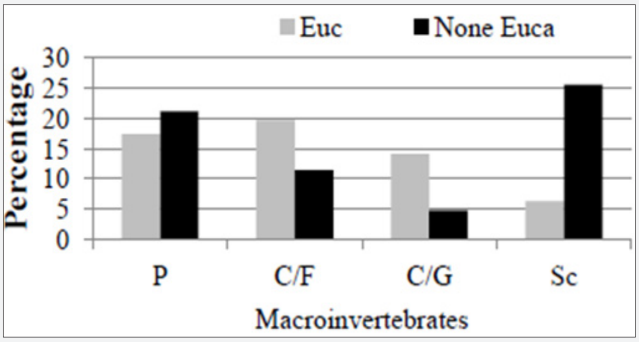

Figure 7 : Functional feeding group with the Eucalyptus and none Eucalyptus sites, P=predators, C/F= collector filtering, C/G=collector gathering, Sc=scraper, No more shredder.

From 20 sampling site the percentage of ECT macroinvertebrate diversity along the stream under none Eucalyptus vegetation was recorded 71.15% where as the percentage of Chironomidae in the stream under Eucalyptus vegetation was recorded 25.14% followed by 9.34 % in the stream under none Eucalyptus vegetation (Figures 3-7).

Diversity Measures

Based on the diversity analysis, macroinvertebrates abundance in streams under none Eucalyptus vegetation was ranged from 50 at site K1 to 399 at site B2; whereas, in streams under Eucalyptus vegetation was ranged from 37 (K5) to 209 (K9). The taxa richness of streams under none Eucalyptus vegetation was ranged from 9 families at site K1 to 17 families at site K2, K3 and B1 whereas in the streams under Eucalyptus vegetation was ranged from 4 at site B6 to 12 at site K9. The Shannon diversity index in the stream under Eucalyptus vegetation was lowest at the site B6 (1.01) and higher at the site of K5 (1.76) whereas in the stream under none Eucalyptus vegetation was lowest at site B5 (1.62) and higher at site K3 (2.3). The rest diversity index is explained in detail in (Table 4). The richness and alpha values indices were large in the streams under none Eucalyptus vegetation than the streams were flow under Eucalyptus vegetation. On the other hand, the remaining diversity indices of macroinvertebrate were almost that have the same values (Figure 8).

Table 4: The richness, abundance, dominance and diversity indices of macroinvertebrate community in selected tributary of Gilgel Gibe River, southwestern Ethiopia, 2015.

Vegetation type	Site Code	Taxa Richness	Individuals	Dominance (D)	Simpson (1-D)	Shannon (H)	Brillouin	Margalef	Eveness (J)	Fisher_α
None Ecualyptus	K1	9	50	0.37	0.63	1.48	1.27	2.05	0.68	3.20
None Ecualyptus	K2	17	224	0.23	0.77	1.86	1.75	2.96	0.66	4.27
None Ecualyptus	K3	17	87	0.14	0.86	2.30	2.04	3.58	0.81	6.31
None Ecualyptus	B1	17	263	0.17	0.83	2.09	1.99	2.87	0.74	4.06
None Ecualyptus	B2	16	399	0.25	0.75	1.69	1.63	2.51	0.61	3.34
None Ecualyptus	B3	14	364	0.16	0.84	1.97	1.90	2.20	0.75	2.89
None Ecualyptus	B4	15	352	0.20	0.80	1.91	1.84	2.39	0.71	3.18
None Ecualyptus	B5	12	266	0.28	0.72	1.62	1.55	1.97	0.65	2.58
Ecualyptus	K4	12	135	0.24	0.76	1.72	1.59	2.24	0.69	3.18
Ecualyptus	K5	9	37	0.14	0.86	2.07	1.76	2.22	0.94	3.79
Ecualyptus	K6	9	51	0.37	0.63	1.43	1.23	2.04	0.65	3.17
Ecualyptus	K7	11	55	0.24	0.76	1.78	1.55	2.50	0.74	4.14
Ecualyptus	K8	9	39	0.17	0.83	1.95	1.66	2.18	0.89	3.67
Ecualyptus	K9	12	209	0.35	0.65	1.52	1.43	2.06	0.61	2.77
Ecualyptus	B6	4	81	0.42	0.58	1.01	0.95	0.68	0.73	0.88
Ecualyptus	B7	9	191	0.42	0.58	1.16	1.10	1.52	0.53	1.96
Ecualyptus	B8	9	93	0.35	0.65	1.42	1.29	1.77	0.65	2.46
Ecualyptus	B9	7	79	0.29	0.71	1.41	1.30	1.37	0.73	1.85
Ecualyptus	B10	10	49	0.34	0.66	1.46	1.24	2.31	0.63	3.80
Ecualyptus	B11	11	110	0.35	0.65	1.38	1.26	2.13	0.58	3.04

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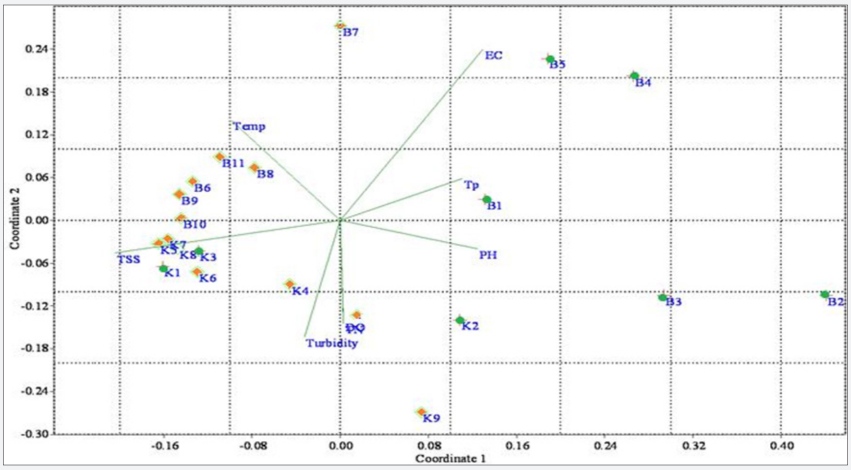

Figure 8 : Non-metric multidimensional scaling (NMDS) analysis of environmental data and sampling sites using Euclidian distance.

Distribution of indices between Eucalyptus and none Eucalyptus sites

Distribution of the indices is shown using box plots. As it can be depicted from the box plots (Figure 9) some indices, such as the Abundance, Simpson, Margalef, Dominance, Brilloun and Shannon were able to discriminate between Eucalyptus and none Eucalyptus sites. Among diversity indices, Richness, Brillouin, individuals, Margalef, %ET, %ECT, %EOT, % Chiron, %Sc and %G/C were significantly discriminate between Eucalyptus and none Eucalyptus plant but the others were not discriminate (Table 5).

Table 5.

Indices	P-value	Discrimination between groups
%ET	0.0004	Eucalyptus and none Eucalyptus
%ECT	0.0016	Eucalyptus and none Eucalyptus
Richness	0.0019	Eucalyptus and none Eucalyptus
% Sc	0.002	Eucalyptus and none Eucalyptus
Brillouin	0.0069	Eucalyptus and none Eucalyptus
Abundance	0.0087	Eucalyptus and none Eucalyptus
% Chiron	0.0109	Eucalyptus and none Eucalyptus
%EOT	0.0206	Eucalyptus and none Eucalyptus
Margalef	0.0308	Eucalyptus and none Eucalyptus
%G/C	0.049	Eucalyptus and none Eucalyptus
Simpson-1-D	0.0641	None
Alpha	0.1427	None
%F/C	0.1643	None
%Odon	0.1897	None
Shannon	0.206	None
%Trico	0.237	None
%P	0.3959	None
Equitability-J	0.5371	None

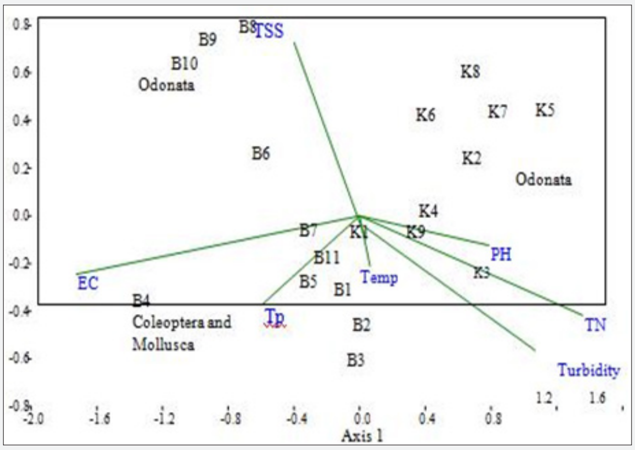

Figure 9 : CCA bi-plot showing the distribution of macroinvertebrate with influencing of environmental variables in selected tributary.

Macroinvertebrate Distribution based on Functional Feeding Group

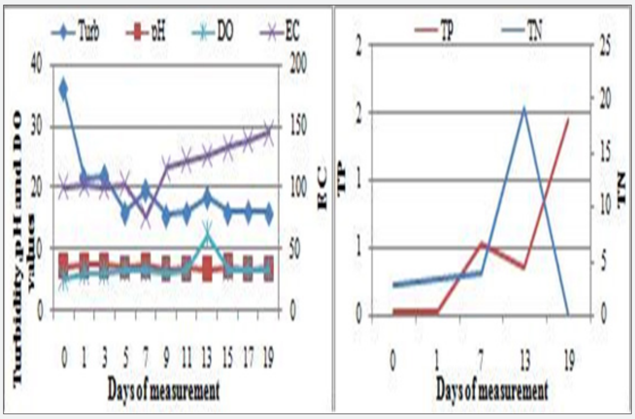

Figure 10 : Water quality characteristics of the control water samples.

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The streams under none Eucalyptus vegetation were majorly dominated by scrapers 25.45% while the streams under Eucalyptus vegetation were majorly dominated by collector-filterer 19.57%. More diversity of macroinvertebrate was recorded in streams under none Eucalyptus vegetation as indicated in (Figure 10).

Multivariate Analysis Results

Non-Metric Multidimensional Scaling: NMDS analysis showed that the samples could be categorized in to two different groups. NMDS categorized the streams were flow under none Eucalyptus and Eucalyptus vegetation. The sampling sites K2, B1, B2, B3, B4, B5 and k9 were grouped in to one group which was flow under the stream of none Eucalyptus vegetation except k9. The sampling sites K1, K3, K4, K5, K6, K7, K8, B6, B7, B8, B9, B10 and B11 were grouped in to another group which was flow under Eucalyptus vegetation except K1 and K3. K1 and K3 were grouped in to Eucalyptus vegetation of sample site as indicated in (Figure 11).

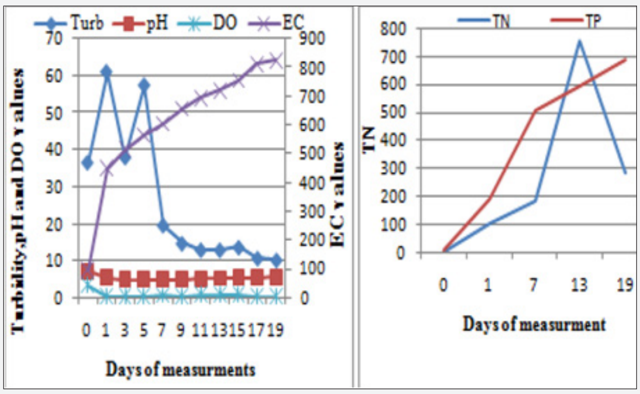

Figure 11 : Water quality characteristics of the Eucalyptus leaf water samples.

Relationship between Macroinvertebrate Community and Environmental Predictors: The species-environment correlation coefficients explain axis one and two of the CCA bi-plot were 57.74%. From this biplot, the first axis was positively correlated with the environmental variables of TSS, water temperature, TN, turbidity and pH, with the sites of K2, K3, K4, K5, K6, K7, K8 and K9 and with the species of Odonata. CCA axis 2 was positively correlated with environmental variables of TP and EC with macroinvertebrates of Coleoptera and Mollusca along the site of K1, B2, B3, B4, B5, B7 and B11 and negatively correlated with that of TSS, water temperature, TN, turbidity and pH. For this analysis DO were removed because of overlapping with that of TN. In the other hand B6, B8, B9 and B10 positively correlated with environmental variable of TSS and species of Odonta.

Relationship between Macroinvertebrate Community and Environmental Predictors: The species-environment correlation coefficients explain axis one and two of the CCA bi-plot were 57.74%. From this biplot, the first axis was positively correlated with the environmental variables of TSS, water temperature, TN, turbidity and pH, with the sites of K2, K3, K4, K5, K6, K7, K8 and K9 and with the species of Odonata. CCA axis 2 was positively correlated with environmental variables of TP and EC with macroinvertebrates of Coleoptera and Mollusca along the site of K1, B2, B3, B4, B5, B7 and B11 and negatively correlated with that of TSS, water temperature, TN, turbidity and pH. For this analysis DO were removed because of overlapping with that of TN. In the other hand B6, B8, B9 and B10 positively correlated with environmental variable of TSS and species of Odonta. Effects of different leaf litter on physicochemical characteristics.

Control group (water without leaf): The physicochemical parameter of water without leaf litter in laboratory activity was showed that EC was increased while pH, turbidity, and DO were decreased. TN was decreased while TP was increased within seven days interval as indicated.

Eucalyptus Leaf in the Experimental Water: The effects of Eucalyptus leaf litter on physicochemical parameter of water shown that the values of EC was increased with decreasing of DO, turbidity and pH within three days interval and TN and TP were increased within seven days interval but TN was decreased in the last day measurement. However, the pH of this experiment was more acidic 4.82-5.48 as indicated in (Figure 12).

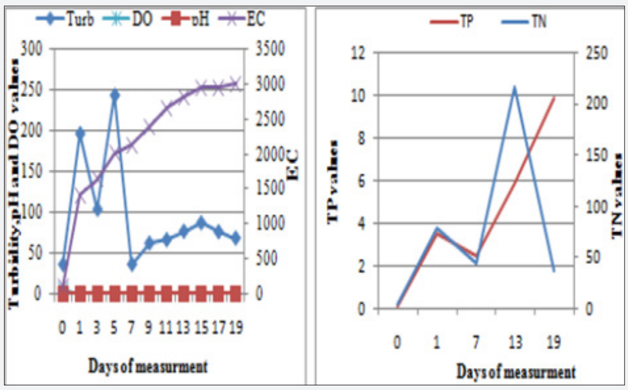

Figure 12 : Water quality characteristics of the Croton macrostachyus leaf water samples.

Croton macrostachyus in the experimental water: *Croton macrostachyus* had increased the values of electrical conductivity from 99μc/cm to 3007μc/cm. TN was decreased and TP was increased within 7 days interval, while the rest parameters that are turbidity, dissolved oxygen, pH and DO saturation were decreased as indicated in (Figure 12).

Ficus sure in the experimental water: Ficus sure plant leaves had significantly increased the rates of EC which was measured 99 μc/cm to 1660μc/cm whereas, the values of turbidity and DO was decreased. The pH values of water were it ranged between 6.65-7.7. TN and TP were decreased within seven days interval (Figure 13).

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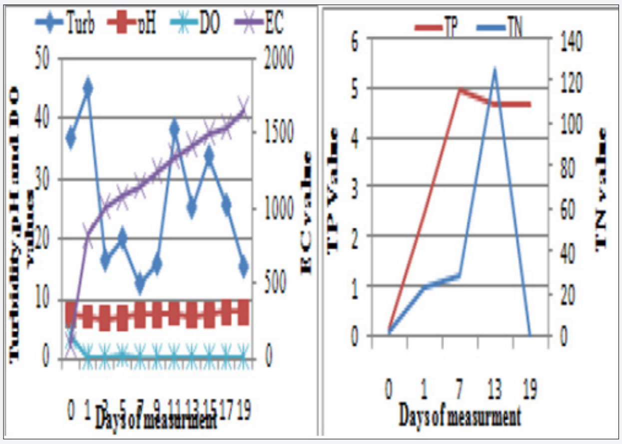

Figure 13 : Water quality characteristics of the Croton macrostachyus leaf water samples.

Salix subserrata leaf litter and water: The effects of salix leaf were almost similar with that of eucalyptus leaf on water physico chemical characteristics. As concentration of electrical conductivity was increased within three days interval for one month whereas the pH value, dissolved oxygen, turbidity were decreased. TN was decreased in the last day where as TP was increased when EC increased as indicated in (Figure 14).

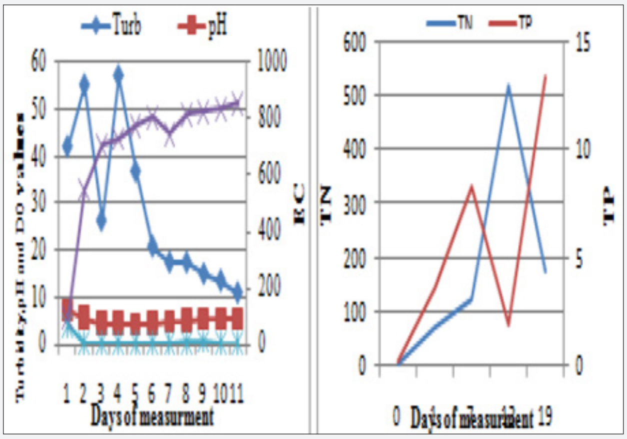

Figure 14 : Water quality characteristics of the Salix subserrata leaf water samples.

Discussion

This study investigates the effects of Eucalyptus plant on water quality and macroinvertebrates diversity in selected tributary streams of Gilgel Gibe River, South-western Ethiopia. Thoughtfully the aquatic ecosystem and diversity of macroinvertebrates are affected by water quality parameters, the availability of exotic plants such as Eucalyptus and the removal of native riparian vegetations [33,34]. The high values of pH, DO, TN, and TP were recorded in the streams under none Eucalyptus vegetation. On the contrary, low values of EC, TSS and turbidity were found. The reason for elevated values of TSS, turbidity, EC in the streams under Eucalyptus tree could be due to the effects of the leaf litter and washing of cloth in the streams. The values of TN, TP and pH were low under the streams of Eucalyptus tree. This might be due to reducing of nutrient cycling by Eucalyptus tree with similar finding of [35-37]. The values of pH in the streams under none Eucalyptus vegetation was recorded 7.68 while in the streams under Eucalyptus vegetation was recorded 6.86. A laboratory experiment also indicates that the pH value revealed low in Eucalyptus leaf litter. This might be due to phenolic acid released from Eucalyptus leaf litter as it was reported by [38]. Therefore, in this study the water quality parameters such as pH, DO, TN, and TP were positively correlated with that of streams under none Eucalyptus vegetation with similar result was reported by [39]. As experimental laboratory results of water samples containing leaf litters shown that the EC and TP were continuously increasing while, turbidity, TN and DO were continuously decreasing until the last day of the experiment. This might be due to the releasing of ions from the leaf litter. In all plant leaf litters TN were gradually decreased. This might be due to the elimination of nitrogen by microorganisms as it was reported by [40]. Therefore, this experiment clearly shown that the Eucalyptus leaf litters can affect the physicochemical parameters. This could be the main factor that can affect the diversity of aquatic macro invertebrates. Low diversity of macro invertebrates was also recorded under the streams of Eucalyptus tree. In these streams, order Ephemeroptera 18.15% was dominant with dominant family of Caenidae 53.4%, order Odonata 17.1% with the dominant family of Coenagrionidae 61.26% followed by order Diptera 8.65% with the dominant family of Chironomidae 94.06%. This might be due to those macroinvertebrates are pollution tolerant and they can survive under Eucalyptus tree with similar finding reported by Alber 2007. On the hand, in the streams under none Eucalyptus vegetation, order Ephemeroptera 43.59% was dominant with dominant family of Beatidae 34%, order Tricoptera 15.6% with the dominant family of Haydropsychidae 96% followed by order Diptera 8.65% with the dominant family of Chironomidae 52%. Pollution sensitive macroinvertebrates were dominant in the stream of under none Eucalyptus vegetation as it was reported by [41]. In non Eucalyptus vegetation such as Ficus sure and Croton macrostachyus leaf litters the pollution sensitive macroinvertebrates were more colonized. In parallel study by Chalchisa [42]. The artificial substrate without leaf litter was more convenient for the colonization of macroinvertebrate as compared to substrate containing leaf litter. Among leaf litters Ficus Sure showed relatively more colonized by macroinvertebrate than the other litters. But Eucalyptus grandi shows a minimum diversity of macro invertebrate colonization. In contrast, sensitive macro invertebrates were low colonized in Eucalyptus leaf. The diversity of EOT, ECT and ET macroinvertebrates were more diverse in the stream of none Eucalyptus vegetation than that of streams under Eucalyptus vegetation. This might be due to the variation of electrical conductivity with in vegetation type

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with similar finding reported by [43]. The functional feeding groups of scrapers (25.45%) were dominant in the streams under none Eucalyptus vegetation. In the contrast, Filtering/ collectors (19.57%) were dominant in the stream under Eucalyptus vegetation. As study conducted [44-50], Reported that pollution sensitive macroinvertebrates were dominant in the stream under riparian vegetation. Based on the None-metric multidimensional scaling analysis, the relationship between physicochemical parameters and sampling sites using Euclidian distance were determined. NMDS were clearly categorized the streams flow under none Eucalyptus and Eucalyptus plantation [51-68]. The streams under none Eucalyptus vegetation sites were categorized in to one group and significantly positively correlated with environmental variables of TP, TN, DO and pH. In contrast, the streams under Eucalyptus vegetation were significantly positively correlated with environmental variables of turbidity, TSS, and EC.

Conclusion

Water quality under the streams of none Eucalyptus vegetation was significantly positively correlated with TN, pH and TP. In contrast turbidity, TSS and EC were positively correlated with Eucalyptus tree. From macroinvertebrate diversity order Ephemeroptera, and Tricoptera were dominantly found in the stream under none Eucalyptus vegetation whereas, Odonata, and Diptera were dominantly found in the streams under Eucalyptus vegetation. However, the occurrence of macroinvertebrate diversity seemed to be more related with the streams under none Eucalyptus vegetation than to the stream under Eucalyptus vegetation. EC and TP were continuously increasing until the last day of the experiment and continuous decreasing of DO, TN and turbidity were recorded.

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